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"CARFAX" TRAFFIC INFORMATION SERVICE : preliminary field assessment of the ring system

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'CARFAX' TRAFFIC INFORMATION SERVICE: PRELIMINARY FIELD ASSESSMENT OF THE RING SYSTEM

M.J. Kallaway, M.A.

Summary

The Report describes a series of field measurements made to assess the performance of the BBC proposed Traffic Information Service employing the 'ring' system.

In the ring system, the motorist's receiver is activated by the strongest signal available from a group of local transmitters by making use of the f.m. 'capture' effect, in conjunction with an f.m. signalling system. The extent of the service area of each transmitter is determined by the ratio of its signal strength to that of the surrounding transmitters.

During the field measurements, emphasis was placed on investigating the accuracy with which service area boundaries could be positioned in practice. The effect of local influences on the ratio of the signal-strengths received from two transmitters, one at Kingswood Warren, the other at Brookmans Park, was studied in some detail. In addition, the service area of one transmitter was measured with the other transmitter acting in the ring mode.

In general, the ratio of signal strengths received from the two transmitters was not greatly affected by local influences. Even in worst-case areas, such as Central London, the unevenness of the boundaries should never extend over more than a few kilometres. The Report concludes that in a practical system the service area boundaries of transmitters should be fairly well defined.

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'CARFAX' TRAFFIC INFORMATION SERVICE: PRELIMINARY FIELD ASSESSMENT OF THE RING SYSTEM

M.J. Kallaway, M.A.

1. Introduction

The BBC has proposed[1] a traffic information system* in which the United Kingdom would be served by a large number of low-power m.f. transmitters, all operating on the same frequency. Each transmitter would serve a fairly small area, and the transmitters would operate on a time-sharing basis to prevent mutual interference. The advantage of this proposal is that the motorist will receive messages that are relevant only to his local area and will not be bothered by irrelevant information concerning more distant areas.

Recently a 'ring system'[2,3,4] has been developed for controlling the activation of motorists' receivers and hence defining the limit of the service area of each transmitter. The ring system is intended to ensure that a receiver is activated only by the strongest signals from local transmitters. The strongest signal is selected using 'f.m. capture effect', which allows repeatable and accurate results to be obtained from a cheap receiving system.[5]

In the ring system, the boundary of the service area for any one transmitter is determined by deliberate jamming or inhibiting of the START signal which heralds every message. The process is described briefly below.

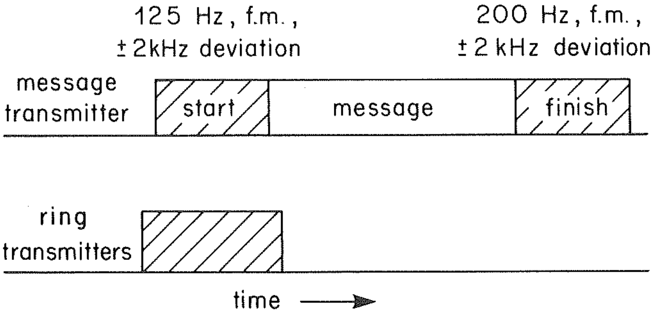

Fig. 2 - Sequence of events during operation of the ring system

In Fig. 1, which shows part of an idealised lattice of motoring-service transmitters, the transmitter labelled T_0 is the message-carrying transmitter, and the six transmitters, T_1 to T_6, which encircle T_0, are the 'ring' transmitters for T_0. Every transmitter can serve as a message transmitter and, when in the message mode, will use its surrounding transmitters as ring transmitters.*

Fig. 2 shows the sequence of events whenever transmitter T_0 radiates a message. Transmitter T_0 first radiates a START signal; this consists of a 125 Hz tone which frequency-modulates the carrier with a peak deviation of ±2 kHz. The six surrounding ring transmitters each radiate a c.w. 'jamming' signal for a period that 'straddles' the START signal from the message transmitter.

A receiver situated at point P in Fig. 1 will receive its predominant signals from transmitters T_0 and T_1. If the signal from T_0 is stronger than that from T_1, 'f.m. capture effect' will ensure that the START signal from T_0 is

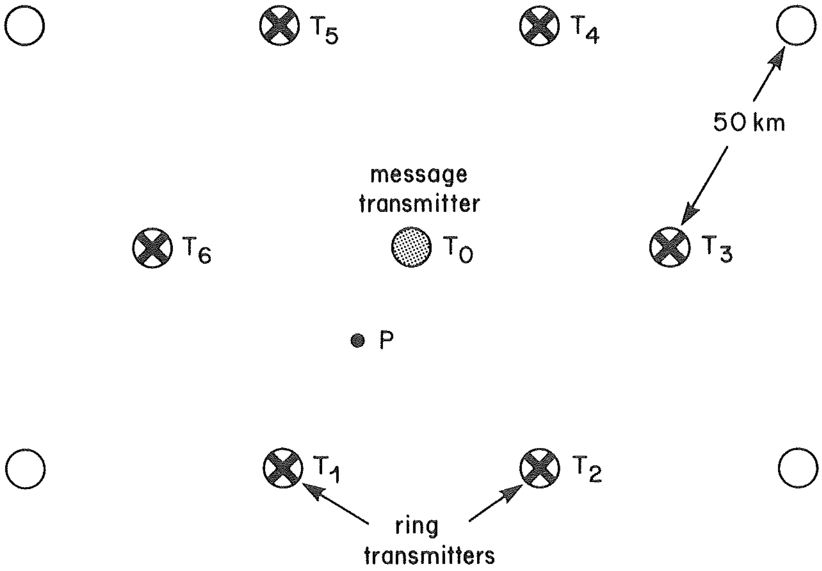

Fig. 1 - Ideal lattice of transmitters

received. Conversely, if the signal from the jamming transmitter T_1 is stronger than that from T_0, capture effect will cause the START signal to be suppressed. With the signal parameters chosen, capture effect is very pronounced, so that a small change in the ratio of the received signals from T_0 and T_1 causes a very large change in the level of the demodulated START tone; a simple decision-circuit in the receiver then allows the receiver to become activated, or not, according to the demodulated START tone level.

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* This system has come to be known as 'CARFAX'.

* In this Report, the term 'ring transmitter' is used to describe a transmitter operating in the jamming or inhibiting mode and the term 'ring signal' is used to describe the signal radiated by a ring transmitter.

Thus the boundary of the service area of each transmitter is determined by the ratio of its signal strength to that from the surrounding transmitters. Under ideal propagation conditions, with uniform ground conductivity, the ratio of signal strengths would vary with the location of the receiver in a highly predictable manner. Hence, the limits of each service area would be both very abrupt and well defined. However, in practice, the signal strengths from each transmitter will vary due to topographical influences; the ground conductivity will vary from place to place and buildings and other man-made structures will also have an effect. Since at receiving sites the signals from the various transmitters arrive from different directions, the local effects on the strength of each signal will be different, causing a change in their ratio. Such practical imperfections in propagation conditions will lead to the individual transmitter service areas having rather uneven boundaries.

It was known that local topography causes the absolute received signal-strength of a transmitter to vary over a range of about 10 dB. However, there was no information available about the way in which the ratio of signal-strengths from different transmitters would vary, although it was expected that the variations in ratio would be generally less than variations in strength. Hence, it was expected that the extent of any unevenness in the boundaries of service areas would be relatively small.

This Report describes a series of field measurements made to assess the practical performance of the ring system. Emphasis was placed on investigating the practical limitations on the accuracy with which the boundaries of transmitter service areas could be positioned. The measurements were made in the London area using two transmitters, one to the north of London at Brookmans Park, the other to the south at Kingswood Warren. Both transmitters operated at 534 kHz.*

2. Field measurements

2.1. General

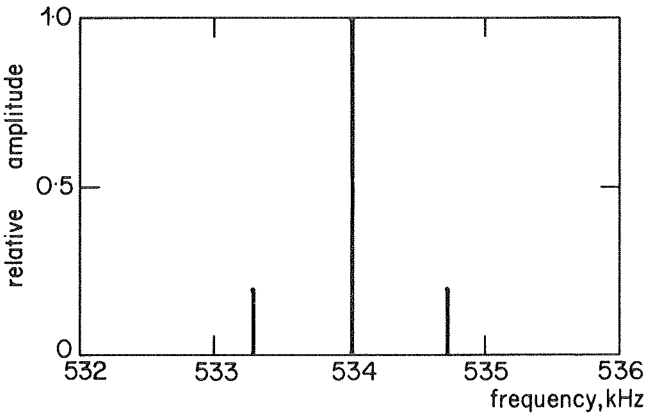
Two sets of measurements were made during the preliminary field-trial.

In the first set, measurements were made of the ratio of the signal-strengths as received from the transmitters at Brookmans Park and Kingswood Warren. These measurements were made to indicate the nature of directional propagation effects and the influence of different types of topography, such as urban and rural areas, was studied in some detail.

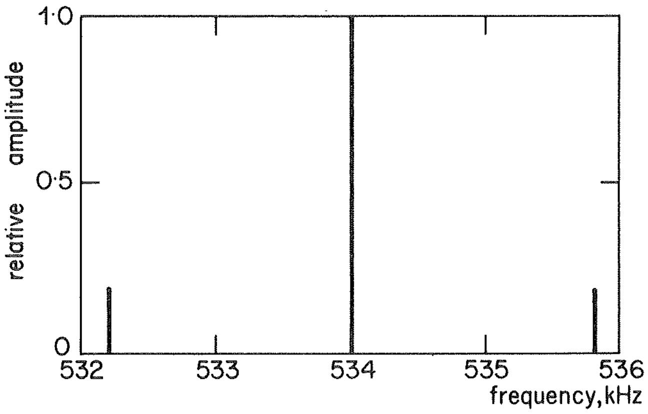
The second set determined for each of two different transmitter power ratios the limits of the service area of one transmitter with the other transmitter in its ring mode. These measurements show directly the likely degree of roughness or unevenness of service area boundaries.

2.2. Signal-strength ratio measurements

It is difficult to measure directly the signal-strength ratio of two c.w. signals received from two transmitters operating simultaneously on the same frequency. An indirect method was therefore devised in which the signals from the two transmitters were each amplitude-modulated by tones of different frequency. Hence, the output signal from each transmitter contained a carrier-frequency component plus an upper and a lower sideband. Since the sidebands from the two transmitters were of different frequencies, they could be readily identified and the ratio of the signal-strengths from the two transmitters at any point was then found by measuring the ratio of the levels of the sidebands. For the Brookmans Park transmitter, the frequency of the tone was 700 Hz, and for the Kingswood



Brookmans Park transmitter



Kingswood transmitter

Fig. 3 - Spectra of signals from transmitters during signal-strength ratio measurements

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* The frequency for the forthcoming field trial has now been fixed at 526·5 kHz.

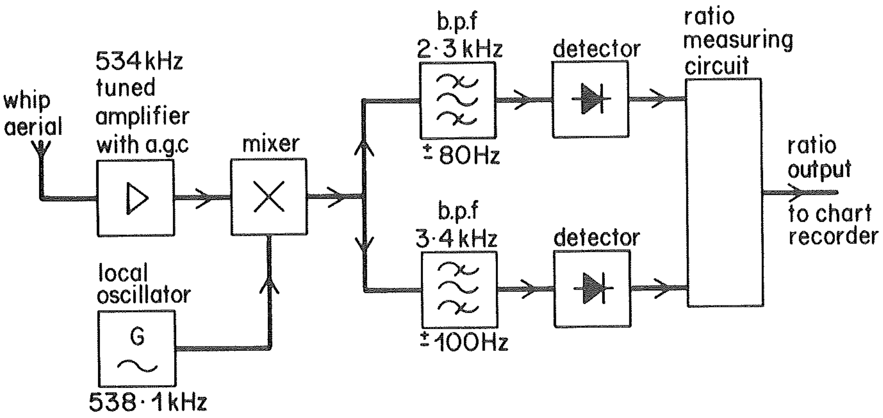


Fig. 4 - Signal-strength ratio measuring receiver

Warren transmitter, it was 1800 Hz: these frequencies were chosen for ease of subsequent filtering, as will be seen. The modulation depth in both cases was 40%. The spectra of the output signals from the two transmitters are shown in Fig. 3.

In order to measure the ratio of the sidebands from the two transmitters, a specially developed receiver was used. A block schematic diagram of the receiver is shown in Fig. 4. Referring to this figure, the r.f. signal from the aerial was applied to an a.g.c.-controlled amplifier, tuned to the carrier frequency of 534 kHz; this amplifier was taken from a receiver of the type described in Reference 6. The output from the amplifier was then applied to one input of a balanced mixer, the other input was fed by a crystal-controlled local-oscillator at 538·1 kHz. Thus, at the output of the mixer, the upper sideband from the Brookmans Park transmitter (see Fig. 3) lay at 3·4 kHz. Similarly, the upper sideband from the Kingswood transmitter lay at 2·3 kHz. The amplitude-ratio of these two sidebands was the same as the ratio of the carriers received from the two transmitters.

The circuitry following the mixer determined the ratio of the two frequency-shifted sidebands and its principle of operation is as follows. The signals at the output of each narrowband bandpass filter were rectified to produce d.c. levels proportional to the signal levels. The two d.c. levels were then applied to the two inputs of a ratio-measuring circuit[7] where the output is a d.c. voltage substantially proportional to the decibel ratio of the two input d.c. levels. The heart of this circuit is a voltage-controlled multivibrator whose 'mark' time is controlled by one of the input d.c. levels and whose 'space' time is controlled by the other input. Hence, the mean level of the multivibrator output is a function of the ratio of the two input d.c. levels; a degree of non-linearity is included in the circuit to improve accuracy.

The output from the complete circuit was applied to a chart recorder so that a mid-scale deflection of the pen indicated equal level of the carriers received from Brookmans Park and Kingswood transmitters. The two extremes of deflection of the pen indicated carrier-ratios of ±12·5 dB, with a linear scale of decibels in between. The performance of the system was such that the indicated carrier-ratio was substantially independent of the absolute levels of the input carriers over a 50 dB range. Within this dynamic range, the indicated carrier ratio was accurate to within about ±1 dB.

For the field-tests, the measuring equipment was installed in a van and fed from a whip aerial about 2 metres long with its base about 2 metres above ground level. Most car radios are fed from whip aerials and it was felt that a whip aerial was appropriate for these tests. If an aerial had been used that was sensitive to the magnetic field, rather than the electric field, a slightly optimistic result might have been obtained, because it is known that the effect of topography on the local level of the magnetic field is somewhat less than its effect on the electric field. The chart drive on the chart recorder used a stepping motor and this was triggered by pulses derived from the speedometer cable of the van. Hence, the length of chart used was directly related to the distance covered during the journey. This meant that it was possible to repeat a series of measurements and compare directly the two chart rolls.

During the field tests, ratio measurements were made over a large area bounded by Regents Park in the North, Crawley in the South, Sevenoaks in the East and Dorking in the West. The van was driven at a speed dictated by local traffic conditions and a total distance of about 400 km was covered. All measurements were made during daylight hours to exclude any sky-wave effects. The e.r.p.'s of the Brookmans Park and Kingswood transmitters were 400 W and 40 W respectively in the direction of London. Both transmitters had roughly omnidirectional radiation patterns.

2.3. Service area measurements

In these tests, the limits of the service area of the Kingswood transmitter were measured with the Brookmans Park transmitter radiating a c.w. signal to simulate a ring transmitter. The Kingswood transmitter was frequency-modulated by a 125 Hz tone with a peak deviation of ±2 kHz to simulate the continuous transmission of the START tone which precedes every message. All locations where the 125 Hz START tone could be received were defined as being within the service area of the Kingswood transmitter. Conversely, all locations where the START tone could not be received were defined as being outside the service area.

The receiver used for these tests was a slightly modified form of traffic receiver of the type described in Reference 6. It is shown in block schematic form in Fig. 5

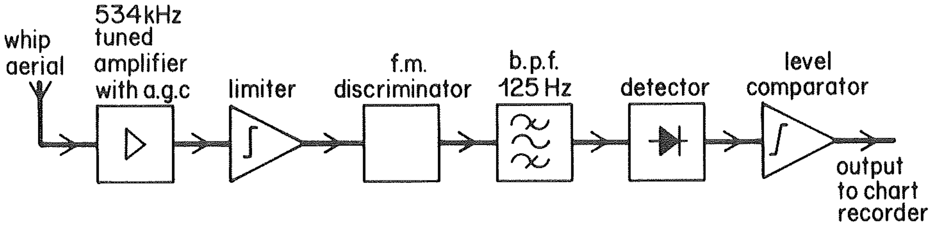


Fig. 5 - Receiver used for service area measurements

and, referring to this figure, the r.f. signal from the aerial was applied to the input of an amplifier tuned to the carrier frequency of 534 kHz. The output from this amplifier was fed to a limiter and f.m. discriminator which demodulated the 125 Hz f.m. tone received from the Kingswood transmitter. The tone was then filtered and passed to a level comparator. The output from the level comparator was in its 'high' state when the signal-strength of the Kingswood transmitter was greater than that of the Brookmans Park transmitter. Conversely, it was in its 'low' state whenever the signal-strength of the Kingswood transmitter was less than that of the Brookmans Park transmitter.

The receiver was installed in a van and the aerial system used was the same as previously described in Section 3.2. The output from the level comparator was applied to a chart recorder so it was possible to see at a glance whether or not the 125 Hz f.m. tone was being received. As before, the drive for the chart was derived from the speedometer cable of the van.

The procedure adopted during this series of tests was, first, to drive the van in an approximate straight line away from Kingswood until the 125 Hz tone was no longer received. Having found the approximate location of the boundary to the service area, the van was then driven so as to cross and re-cross the boundary, the position of which could thereby be more accurately determined. Using this method, the course of the boundary was followed over an arc of about 180°, centred on London. Two complete sets of measurements were made, one with both transmitters operating at full power, and the other with the power of the Brookmans Park transmitter reduced by 8 dB. The 8 dB power reduction was made so that the service area boundary would pass through the centre of London, where the unevenness of the boundary was expected to be greatest.

3. Results of field measurements

3.1. Signal-strength ratio measurements

During this series of measurements it was noticed that the ratio of the signal-strengths from the two transmitters was influenced by many factors. Variations in the ratio were generally higher in built-up areas than in open countryside. Overhead wires were also found to have a significant effect. In some areas most telephone wires are buried underground. In other areas, for example Biggin Hill, most wires are carried on telegraph poles. It was noted that the relative angle of arrival of the signals from the two transmitters was also important.

The results of the field-measurements were carried on a series of chart rolls showing how the ratio of the signal-strengths received from the two transmitters varied with receiving location. The extraction of statistical information from the charts, for future use, was regarded as an important part of the work, and an attempt was made to present the information extracted in such a way as to highlight the importance of each of the factors mentioned above.

After careful consideration, the procedure adopted for analysing the chart recordings was as follows. The charts were divided into lengths corresponding to 1 route-kilometre, for each of which the median value of the ratio of the signal-strengths from the two transmitters was found. The percentage of locations within each route-kilometre where the signal-strength ratio was within ±1 dB of the median was then determined. The process was repeated for locations where the signal-strength ratio was within ±2 dB, ±4 dB, ±8 dB and ±10 dB of the median value.

Each route-kilometre was then categorised according to the local topography and the relative angle of arrival between the signals from the two transmitters. The categories used are listed below.

	Topographical categories	Examples
A	Heavily built-up areas	City of London, Central Croydon
B	Residential urban areas	Hammersmith, Chelsea
C	Suburban areas	Surbiton, Esher
D	Open countryside	Epsom Downs
E	Areas with many overhead cables	Biggin Hill

Angle-of-arrival categories

1. Relative angle of arrival between the signals from the two transmitters in the range 120° to 180°
2. Relative angle of arrival between the signals from the two transmitters in the range 60° to 120°
3. Relative angle of arrival between the signals from the two transmitters in the range 0° to 60°

The results extracted from the chart recordings were combined within the various categories and are presented graphically in Figs. 6 and 7. Each graph shows how the ratio of the signal-strengths from the two transmitters varies for one particular category. Fig. 8 shows a similar graph for all the various categories combined.

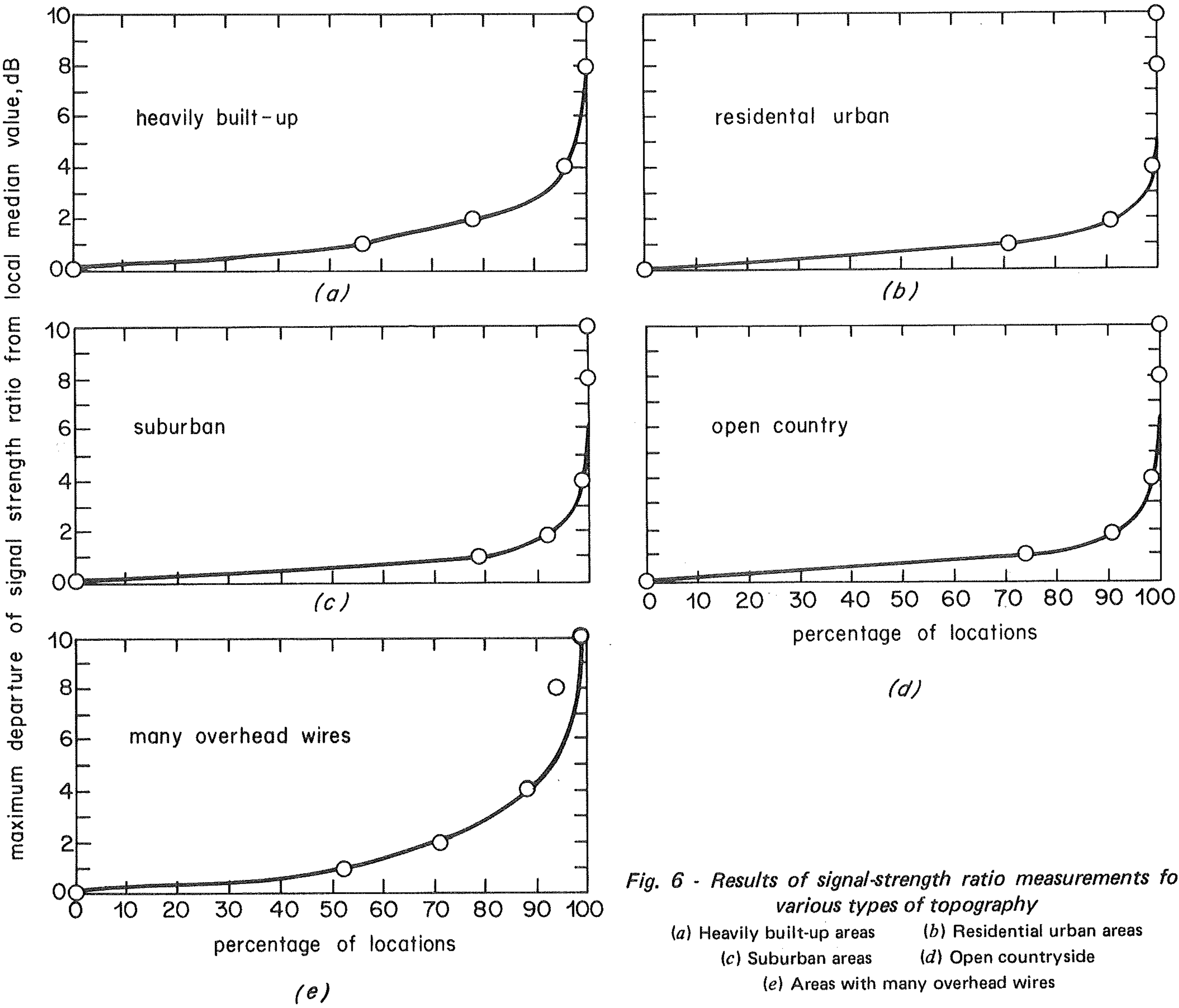


Fig. 6 - Results of signal-strength ratio measurements for various types of topography

(*a*) Heavily built-up areas (*b*) Residential urban areas

(*c*) Suburban areas (*d*) Open countryside

(*e*) Areas with many overhead wires

3.2. Service area measurements

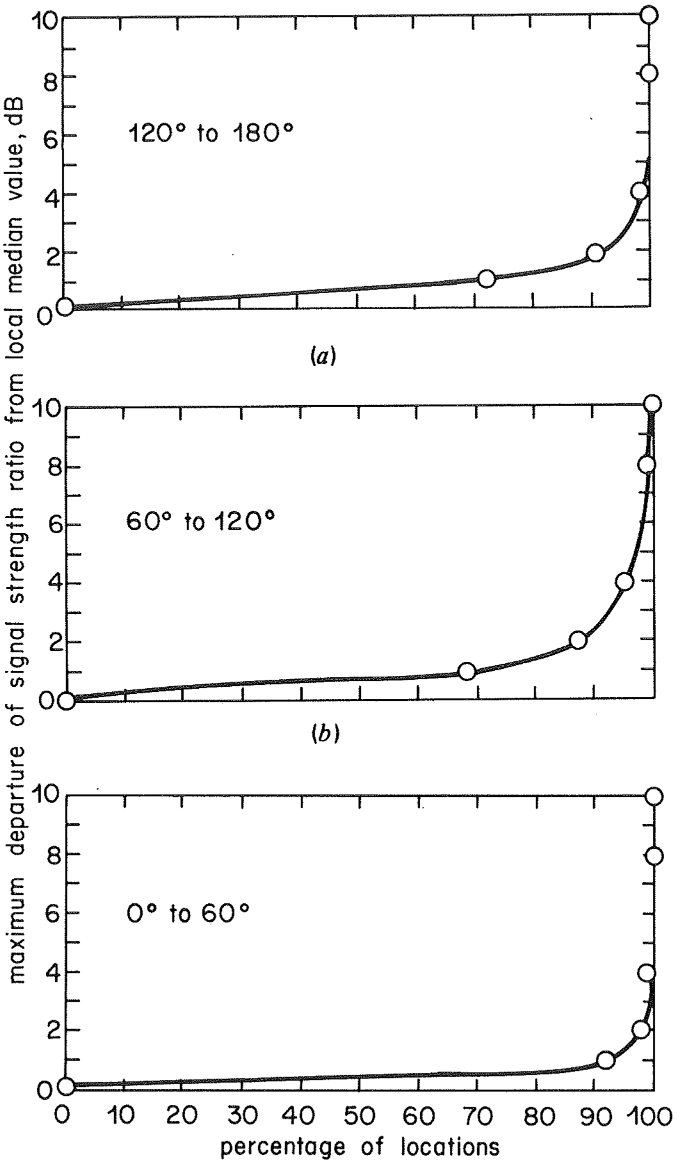
The results of the measurements to determine the limit of the service area of the Kingswood transmitter when the Brookmans Park transmitter was in its ring mode are shown in Fig. 9. In this figure two sets of results are presented, one for the case when the Brookmans Park transmitter was operating at full power, the other when its power was reduced by 8 dB.

In Fig. 9 the crosshatched areas represent the regions where the START tone from the Kingswood transmitter was received at between 5% and 95% of locations. As such, it shows the extent of the jaggedness of the service area boundary. To the north of each crosshatched region the START tone was received at less than 5% of locations. To the south of the region, the START tone was received at more than 95% of locations. Hence, the crosshatched areas shown in Fig. 9 can be viewed as areas of uncertainty where it is not clear whether they are inside or outside the Kingswood service area. Within this region, locations not served by the Kingswood transmitter would be served by the Brookmans Park transmitter.

An example of how the reception of the START tone changes as a vehicle moves across one of the crosshatched areas of Fig. 9 is shown in Fig. 10. This figure shows a short length of the chart roll produced during the field measurements, whilst driving through Morden Park from north to south. Moving from left to right on the figure, in the first kilometre, the START tone was not received at all. Then, the START tone was received sporadically and gradually reception became better until it was received all the time. The area where the reception of the START tone was uncertain extends over about 1 km and is marked on the map shown in Fig. 9.

4. Discussion of experimental results

The field measurements of the variation in the ratio of the signal-strengths received from the two transmitters show that in any small area it remains reasonably constant. This confirms the optimism expressed in the introduction. Looking at Fig. 8 showing the composite results of all the measurements, in 90% of locations the signal-strength ratio is within ±2 dB of the local median value. This result leads



(a)

(b)

(c)

Fig. 7 - Results of signal strength ratio measurements for signals arriving from different angles

(*a*) Relative angle of arrival in the range 120° to 180°
(*b*) Relative angle of arrival in the range 60° to 120°
(*c*) Relative angle of arrival in the range 0° to 60°

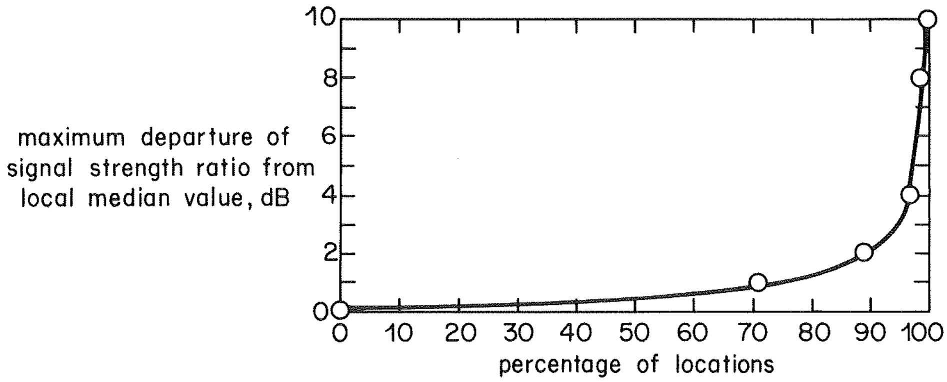


Fig. 8 - Combined results of signal-strength ratio measurements

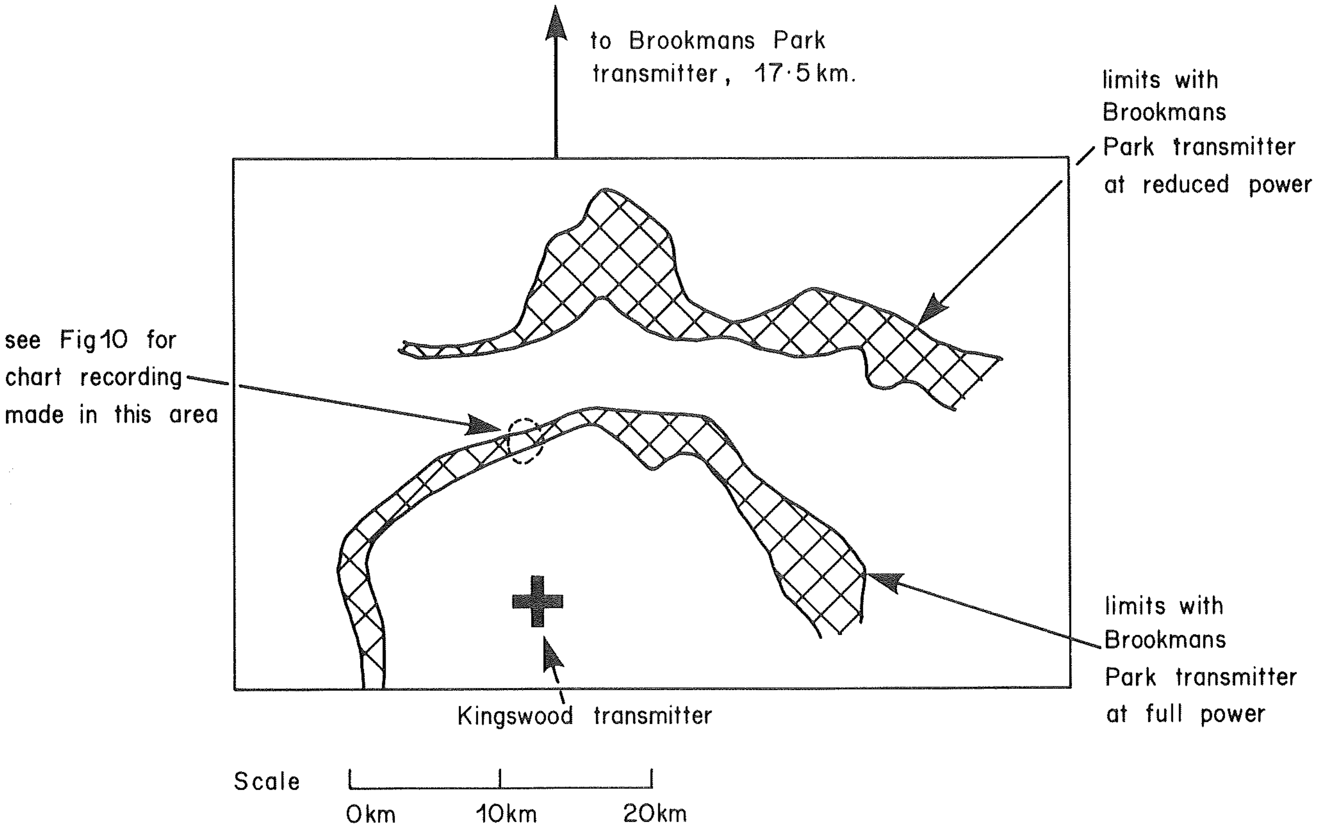

to Brookmans Park transmitter, 17·5 km.
limits with Brookmans Park transmitter at reduced power
see Fig 10 for chart recording made in this area
limits with Brookmans Park transmitter at full power
Kingswood transmitter
Scale
0km
10km
20km

Fig. 9 - Measured limits of service area of Kingswood transmitter

▨ Uncertainty region where START tone from Kingswood transmitter was received at between 5% and 95% of locations

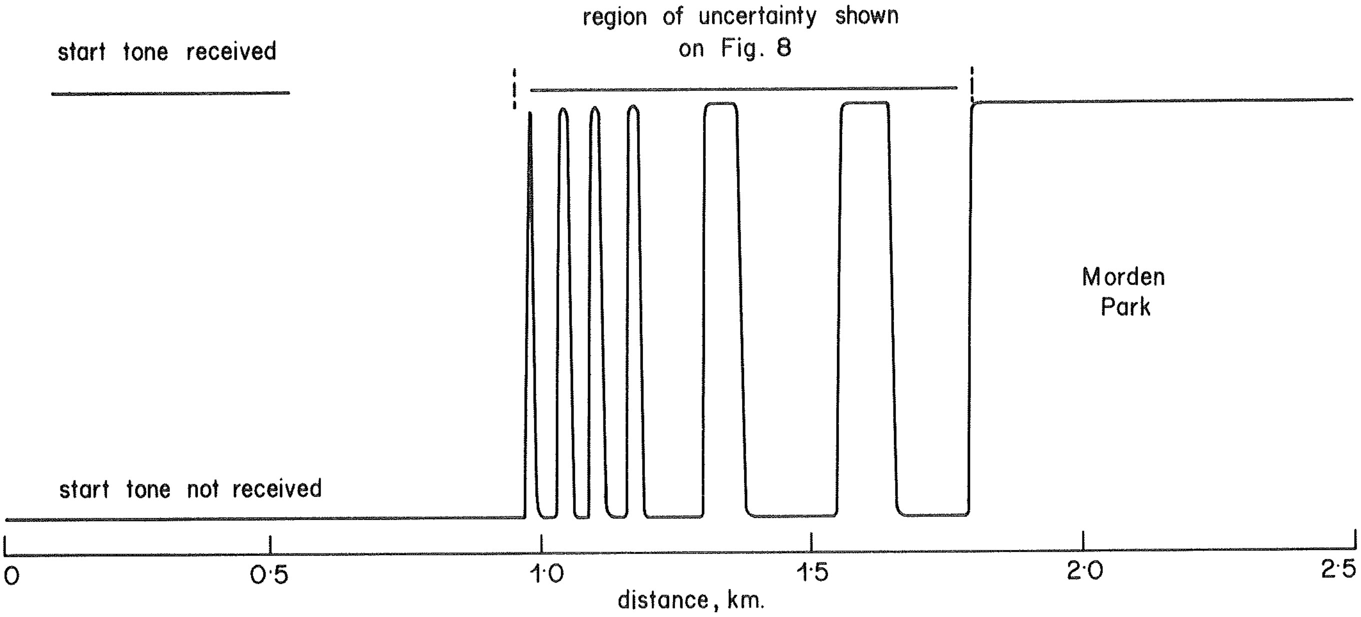


Fig. 10 - Example of chart recording produced during service area measurements

directly to the conclusion that in most areas the service area boundaries of transmitters in the ring system would be fairly well defined.

The variations in signal-strength ratio (see Figs. 6(*a*) and 6(*e*)) were generally the greatest in heavily built-up areas and areas with many overhead wires. For example, in heavily built-up areas 90% of locations have a signal-strength ratio that is within ±3 dB of the local median value. In areas with many overhead wires, the corresponding variation is within ±4·5 dB of the median value. Steel-framed buildings are believed to account for the worsening of the results in built-up areas. The field-measurements showed that such buildings could disturb the signal-strength ratio by up to 10 dB. However, their range of influence was generally restricted to within 100 m from the building. The effect of buildings of similar external size was found to be fairly similar and predictable.

For areas with many overhead wires, it was found to be very difficult to predict what effect any particular set of wires would have in the signal-strength ratio. For example, it was possible to drive along a road and pass under a single telegraph wire which would disturb the ratio by say, 5 dB. Further along the same road there might be a large number of telegraph wires crossing the road and they could have absolutely no effect on the ratio as the vehicle passed underneath. In general, it was not found possible to relate the difference between the two cases to some particular factor, though doubtless if a very close examination of each case had been made, reasons for the difference would have been found. At worst, overhead wires were found to disturb the signal-strength ratio by about 10 dB and their influence was confined within a range of about 25 m from the wire.

The influence of the relative angle of arrival of the signals from the two transmitters on variations in the signal-strength ratio shown in Fig. 7 largely follows expectations. When the signals arrive from the same direction, the variation in signal-strength ratio is very small indeed. When they arrive from opposite directions, the variation is much larger. However, it is interesting to note that the greatest variation occurs when the relative angle of arrival is about 90°. Unfortunately, the results are coloured by the influence of different types of topography. For example, areas where the signals arrived from the same directions were mostly open countryside and areas where the signals arrived from opposite direction were mostly built-up. In areas with many overhead wires (e.g. Biggin Hill) the relative angle of arrival of the signals was about 90°. Hence, it is difficult to say generally how accurate are the results of Fig. 7 since the influence of topography may be masking the true variations due to the relative angle of arrival.

The measurements made of the service area of the Kingswood Warren transmitter shown in Fig. 9 bear out the signal-strength ratio measurements very well. The region of uncertainty at the edge of the service area caused by the jaggedness of the boundary is widest in heavily built-up areas and smallest in rural areas. Also in the vicinity of Biggin Hill where there are many overhead wires the region of uncertainty is fairly large. At best, the region of uncertainty is less than 1 km wide. At worst in, for example, Central London, it is about 7 km wide. On average, it is about 2 to 3 km wide, which is a small fraction of the mean radius of the service area.

From both the signal-strength ratio and service area measurements two important points emerge which are relevant to the planning of the proposed service. First, there is a clear need for an overlap of the service areas of adjacent transmitters. A reasonable overlap of say 5 or 6 km will largely mitigate the effects of the jagged service area boundaries. It is of course desirable to have an overlap so that motorists get advance warning of traffic conditions in an area before they actually enter it. Secondly, if possible the boundaries of service areas should not pass through heavily built-up areas. In fact, it is quite likely that most boundaries would not pass through heavily built-up areas for other reasons. From the viewpoint of feeding information to motorists, towns and cities are best served by a single transmitter; under these conditions, the boundaries of service areas would tend to encircle a town and not pass through heavily built-up areas.

The increase in the jaggedness of service area boundaries due to overhead wires is more difficult to accommodate, particularly as areas with many overhead wires appear to be randomly distributed over the country. The effects can be partially mitigated by increasing the length of the burst of START tone that heralds every message. The range of influence on the signal-strength ratio of overhead wires is relatively small, of the order 25 m. Hence if a receiver were effectively to average the signal-strength ratio over, say, 100 m the effect of the overhead wires would be greatly reduced. In practice, of course vehicles will not all be moving at the same speed, indeed some will be stationary during the START tone. Hence, an increase in the time allowed for averaging the START signal can only be partially successful. It is suggested that the length of burst of the START tone could be increased from its presently proposed value of 0·5 s to 1 s. For a vehicle moving at 70 k.p.h. (~45 m.p.h.) the signal-strength ratio would then be averaged effectively over a distance of about 20 m to 30 m. This is not very long but it would be likely to lead to some improvement in the definition of service area boundaries.

If the above suggestions are put into practice, it is believed that service area boundaries will be fairly well defined. Certainly, any uncertainty in the position of the boundary would not extend over more than a few kilometres, even in worst-case areas. This is borne out by the results shown in Fig. 9.

5. Conclusions

A preliminary field assessment of the ring system has been made which has shown that the boundaries of transmitter service areas should be well defined in a practical system. It is likely that any uncertainty in the precise position of the boundary will never be more than a few kilometres. The effects of uncertainty in the precise position of service area boundaries will be largely overcome by the necessary requirement of an overlap of adjacent service areas.

Measurements made of variations in the signal-strength ratio of signals received from two transmitters have shown that the ratio remains fairly constant within any small area. On average, 90% of locations have a signal-strength ratio that is within ±2 dB of the local median value.

The variations in signal-strength ratio were found to be greatest in heavily built-up areas and areas with many overhead wires. Fortunately, it is undesirable for service area boundaries to pass through heavily built-up areas from the viewpoint of traffic information coverage. Hence, the extra uncertainty of boundary positions in heavily built-up areas is not likely to have much effect on the overall performance of the ring system.

It appears that the effects of overhead wires on boundary definition can be partially overcome by increasing the length of the burst of START tone that heralds every message. This would allow receivers to average out some of the disturbances caused to signal-strength ratios by the wires. It is recommended that the length of the START tone burst be increased from its presently proposed value of 0·5 s to 1 s.

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